PART 1: MULTIPLE CHOICE ANSWER SHEET

YOUR NAME: .....SOLUTIONS.....

INSTRUCTIONS: Using a pen mark your selections on this sheet by using a X. If you need to make a correction make sure you intent is clear.

You may choose to carefully remove this answer sheet

1. (A) [B] [C] [D]
2. [A] (B) [C] [D]
3. (A) [B] [C] [D]
4. [A] [B] [C] (D)
5. [A] [B] (C) [D]
6. (A) [B] [C] [D]
7. [A] [B] (C) [D]
8. (A) [B] [C] [D]
9. [A] [B] (C) [D]
10. [A] (B) [C] [D]
11. [A] [B] (C) [D]
12. [A] [B] [C] (D)
13. [A] (B) [C] [D]
14. (A) [B] [C] [D]
15. [A] [B] (C) [D]
16. [A] (B) [C] [D]
17. (A) [B] [C] [D]
18. [A] [B] (C) [D]
19. [A] [B] [C] (D)
20. [A] (B) [C] [D]
21. [A] [B] [C] (D)
22. [A] (B) [C] [D]
23. [A] (B) [C] [D]
24. [A] (B) [C] [D]
25. [A] [B] (C) [D]

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PART 2 Short Answer (70 marks)

This part contains **nine (9)** questions. Answer **all** questions. Write your answers in the space provided.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

Suggested working time: 60 minutes.

Question 1 **(7 marks)**

For each of the following pairs of substances, provide details of a **chemical** test that would allow the two substances to be distinguished from one another. Equations are **not** required. Use of pH indicators is not considered to be a chemical test.

substances	chemical test	observations
Ni(s) and Mg(s)	eg add dilute HCl(aq) [1]	**Ni(s)** • dissolves to give a green solution • colourless gas evolved [1]
		Mg(s) • dissolves more rapidly to give a colourless sol^n and evolution of a colourless gas. [1]
$NaCH_3COO(s)$ and $NaC\ell(s)$	eg first dissolve solids in water [1] then add $AgNO_3(aq)$ [1] OR add some dilute HCl	**$NaCH_3COO(s)$** no visible reaction upon addition of $AgNO_3$ [1]
		$NaC\ell(s)$ White ppte forms [1] → Vinegar smell produced from the acetate sol^n → no reaction occurs with NaCl(aq)

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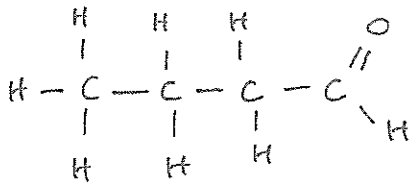
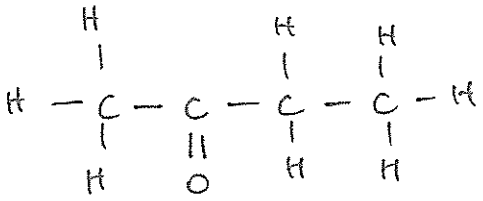
Question 2 **(8 marks)**

(a) 2-methylpropanal, whose formula is $(CH_3)_2CHCHO$, has two structural isomers. In the spaces provided below, draw the full structures showing all H-atoms and give the IUPAC names of these two isomers. (4 marks)

structure	IUPAC name
	butanal
	butanone or butan-2-one or 2-butanone

4 x [1]

2-methylpropanal can be converted into substance Y by heating it with a mixture of sodium dichromate and dilute sulfuric acid.

(b) State an observation that can be made as this reaction proceeds. (1 mark)

Solution changes colour from orange to blue/green

(c) Name the functional group present in substance Y that is **not** present in 2-methylpropanal. (1 mark)

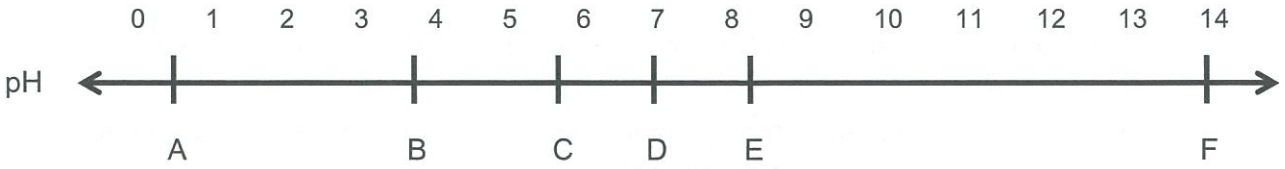
carboxylic acid

(d) Write a balanced half-equation showing the conversion of 2-methylpropanal into substance Y (2 marks)

$(CH_3)_2CHCHO + H_2O \rightarrow (CH_3)_2CHCOOH + 2H^+ + 2e^-$

Question 3 **(6 marks)**

Universal indicator was used to measure the pH of six solutions (each with a concentration of 0.5 mol L^{-1}) and the results are shown in the diagram below.



The six substances were;

KCl HF HCl NH_4Cl KOH KF

(a) Which substance is most likely to be C? Explain your answer using an equation. (2 marks)

NH_4Cl – NH_4^+ weaker acid than HF [1]

$NH_4^+ + H_2O \rightleftharpoons H_3O^+ + NH_3$ [1]

(b) Which substance is most likely to be F? Explain your answer using an equation. (2 marks)

KOH – strong base [1]

$KOH \rightarrow K^+ + OH^-$ [1]

(c) Name the two substances that would produce a buffer when mixed together. Explain your choice. (2 marks)

HF and KF [1]

HF is a weak acid and F^- is its conjugate base. [1]

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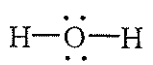
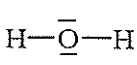
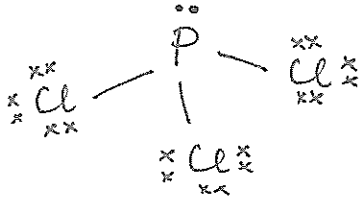
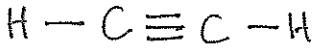
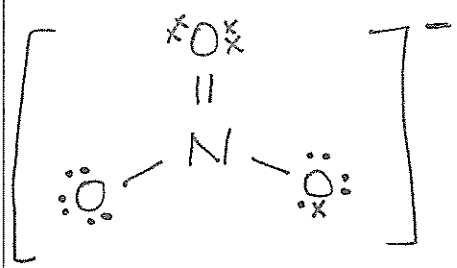
Question 4 **(9 marks)**

For each species listed in the table below, draw the electron-dot diagram or Lewis structure, representing all valence shell electron pairs either as : or as — **and** state or sketch the shape of the species.

(for example, water  or  or  bent, polar)

Species	Lewis structure (showing all valence electrons)	Shape (sketch or name)
phosphorus trichloride PCl_3		pyramidal
ethyne C_2H_2		linear
nitrate ion NO_3^-	 must have a total of 24 e^-	triangular planar

3 x [2] for structures
3 x [1] for sketch/shape.

Question 5 **(8 marks)**

Mitch and Jarrod were carrying out a titration in order to determine the concentration of a sodium hydroxide solution. A 20.0 mL aliquot of standard 0.0274 mol L^{-1} ethanoic (acetic) acid solution was delivered into a conical flask and titrated against the sodium hydroxide solution. This process was repeated until an accurate average titre could be obtained.

(a) What piece of equipment would have been used to deliver the aliquots of standard ethanoic acid into the conical flask? (1 mark)

pipette

(b) What substance should Mitch use for the final rinsing of his burette just prior to it being used? (1 mark)

the NaOH solution

(c) Write the equation for the reaction that would have taken place inside the conical flask, including in your answer only those species that react. (2 marks)

$CH_3COOH_{(aq)} + OH^-_{(aq)} \rightarrow CH_3COO^-_{(aq)} + H_2O_{(l)}$

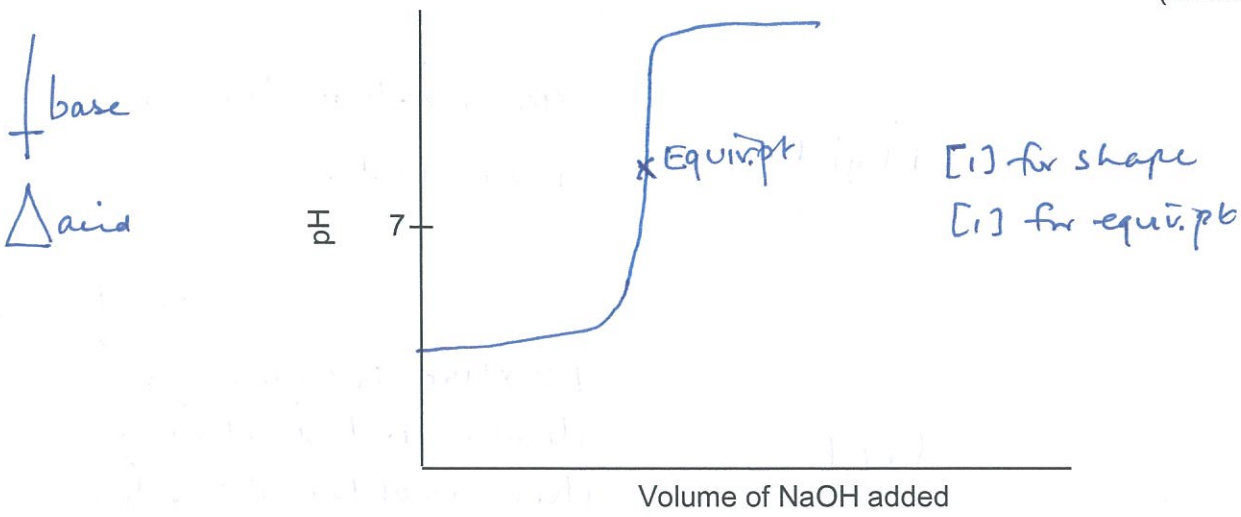
(d) Name an appropriate indicator for this titration. Explain your choice clearly. (2 marks)

phenolphthalein – changes colour in basic pH's. [1]

This titration will have an equivalence point that is basic due to hydrolysis of CH_3COO^- [1]

(e) Sketch a titration curve for the above experiment. Label the equivalence point of the reaction.

(2 marks)



[1] for shape
[1] for equiv. pt

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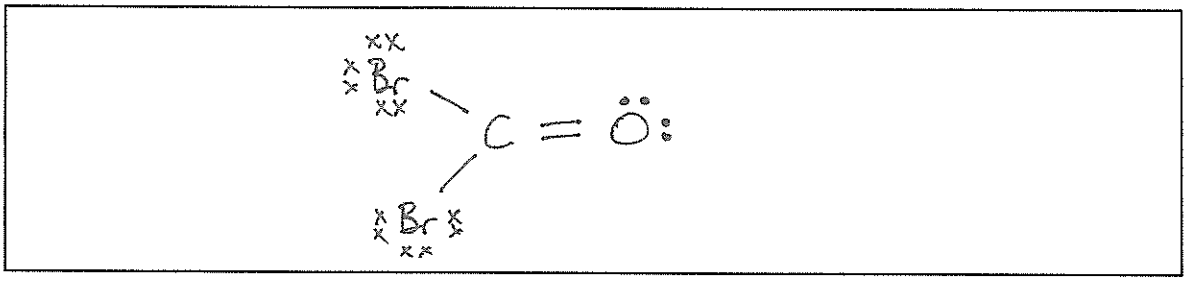
Question 6 **(6 marks)**

Carbonyl bromide ($COBr_2$), also known as bromophosgene, can be produced when the chemicals in fire extinguishers decompose. The following equation represents the endothermic decomposition of carbonyl bromide into carbon monoxide and bromine.

$$\underset{\textit{colourless}}{COBr_2\,(l)} \leftrightharpoons \underset{\textit{colourless}}{CO\,(g)} + \underset{\textit{red}}{Br_2\,(g)} \qquad \Delta H > 0$$

(a) Draw the structural formula for carbonyl bromide, representing all valence shell electron pairs either as : or – . (1 mark)



(b) Write the equilibrium constant expression for the decomposition equation. (1 mark)

$$K = [CO][Br_2]$$

(c) Complete the following table by indicating the direction of the expected shift in equilibrium immediately following the change stated in the table. Give expected observations in each case. (4 marks)

Change	Direction of shift in equilibrium ('left', 'right' or 'no change')	Observations
temperature increase	right	gas mixture becomes more red.
reduce the volume of the container	left	mixture becomes darker red initially then lighter as $\Rightarrow$ lm is established

[1] ↑

4 × [1]

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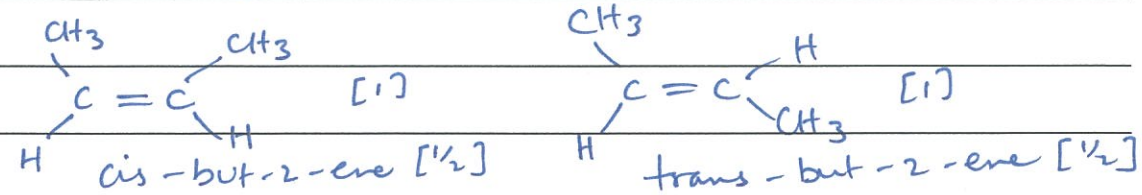
Question 7 **(8 marks)**

(a) But-1-ene and but-2-ene are isomers of C_4H_8. What is the name given to this type of isomerism? (1 mark)

Structural isomers

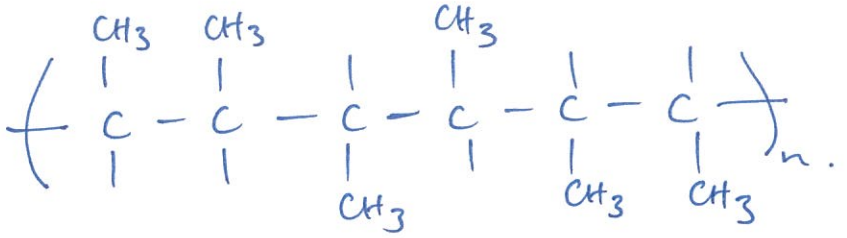
(b) In addition to the type of isomerism displayed by the molecules in part (a), but-2-ene itself exhibits another type of isomerism. State the name given to this type of isomerism, and draw and name the two isomers. (4 marks)

geometrical isomers [1]



cis-but-2-ene [½] trans-but-2-ene [½]

(c) In the space provided, draw a length of polymer chain that could be formed from 2-butene, showing **three** repeating units. (2 marks)



[2]

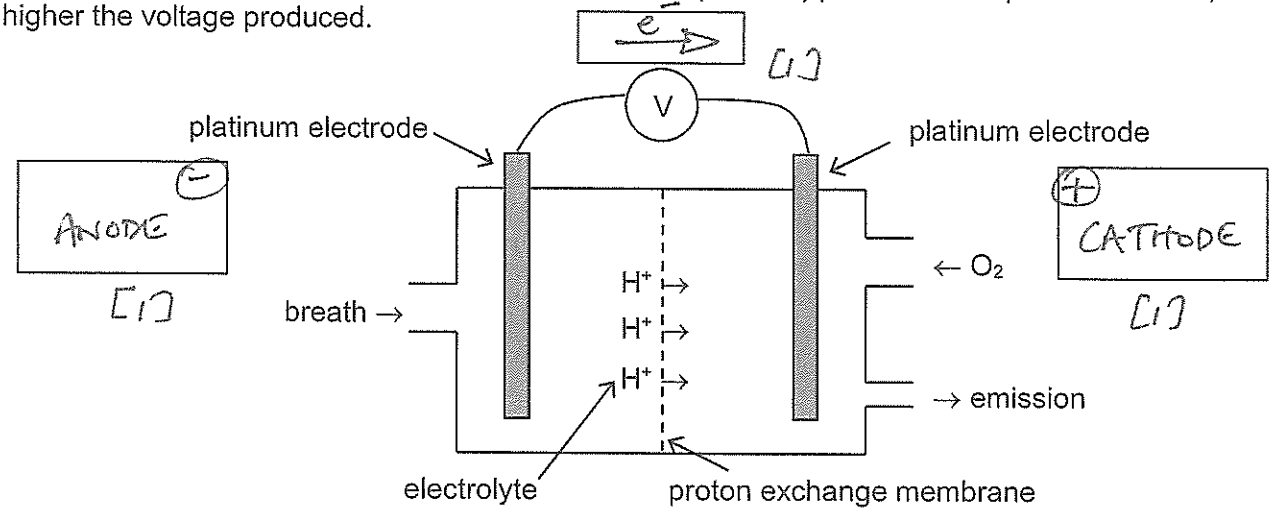
- any structure is OK provided there is only one CH_3 group on each carbon.

(d) State the name given to the type of polymerisation described in part (c). (1 mark)

addition polymerisation

Question 8 (8 marks)

One method that can be used to determine blood alcohol level is using an electrochemical cell based on the design shown below. The more alcohol (ethanol) present in the person's breath, the higher the voltage produced.



(a) In the boxes on the diagram above, label the cathode and anode, the charge of each electrode, and the direction of electron flow. (3 marks)

The relevant half equations for the cell, along with their E^0 values under standard conditions are shown below.

$CH_3COOH\,(l) + 4\,H^+\,(aq) + 4\,e^- \leftrightarrows CH_3CH_2OH\,(l) + H_2O\,(l)$ E^0 - 0.67 V

$O_2\,(g) + 4\,H^+\,(aq) + 4\,e^- \leftrightarrows 2\,H_2O\,(l)$ E^0 +1.23 V

(b) What is the purpose of the platinum electrodes? (1 mark)

provide an inert electrical conductor

(c) Write an overall equation for the cell. (1 mark)

$O_2 + CH_3CH_2OH \rightarrow CH_3COOH + H_2O$

(d) Calculate the emf of the cell under standard conditions. (1 mark)

$1.23 - (-0.67) = 1.90\ V$

A variation of the 'breathalyser' cell above could involve breathing into a tube containing absorbent paper that is soaked in an acidified potassium dichromate solution.

(e) What colour change would you expect to observe if alcohol was present on someone's breath? (1 mark)

orange to blue/green

(f) Why are dichromate solutions usually acidified in redox reactions? (1 mark)

to provide the H^+ ions needed for the half equations

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Question 9 **(10 marks)**

Tetrafluoroethene is produced industrially by a series of reactions, the final of which is shown below.

$$2CHClF_2\,(g) \leftrightarrows C_2F_4\,(g) + 2HCl\,(g)$$

(a) What conditions of pressure (high or low) would favour a high yield of tetrafluoroethene? Explain your answer. (3 marks)

low pressures [1]

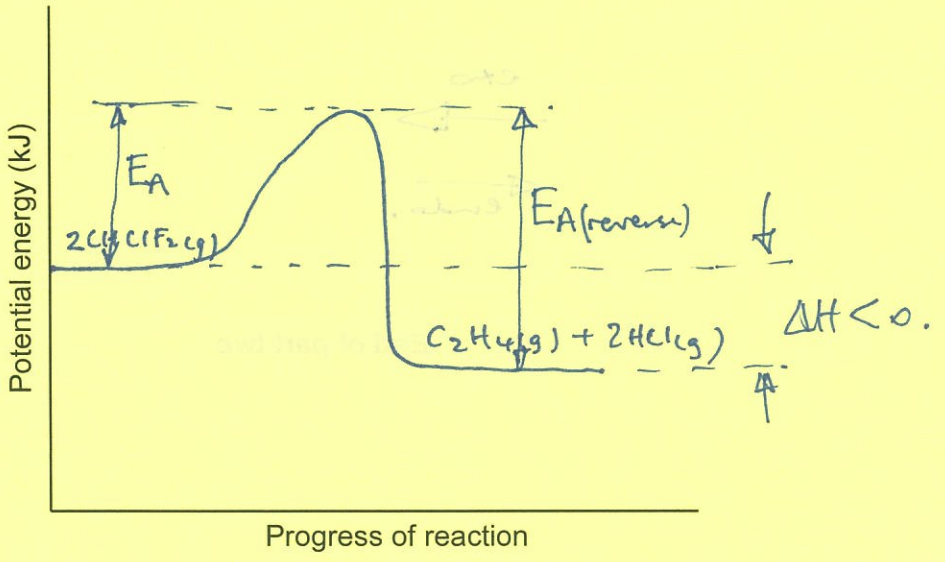
With two gas molecules on the LHS and three on the right, low pressures will favour the side with more gas molecules ie the RHS. [2]

exo. →

← endo

As temperature increases, the concentration of tetrafluoroethene in the system decreases.

(b) Sketch a potential energy diagram for the above reaction. Label the activation energy, reverse activation energy, and the enthalpy change. (4 marks)



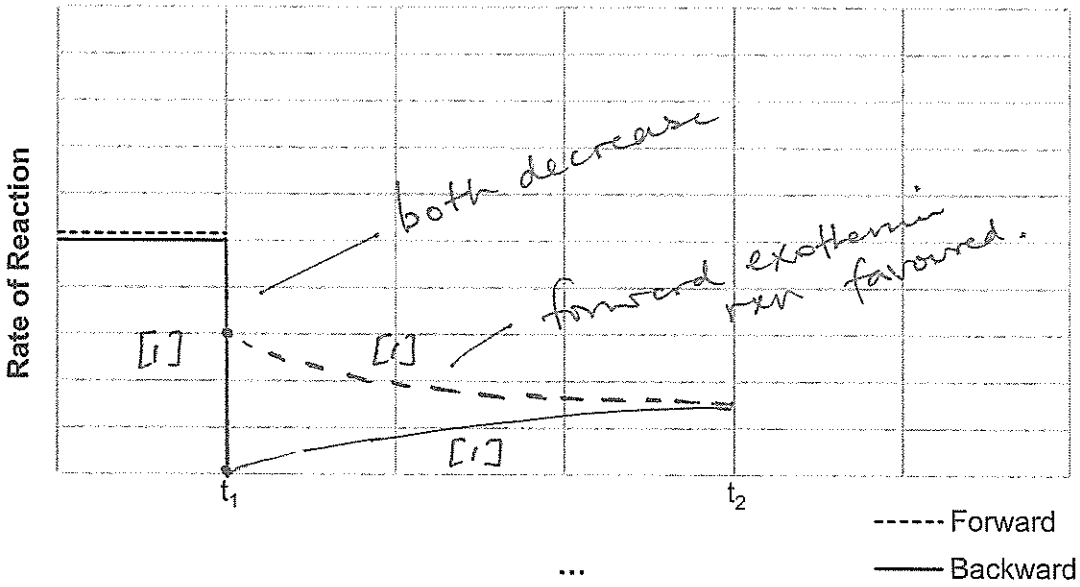
[2] for sketch and figuring out it is an exothermic rxn.

2x[½] for E_A's

[1] for ΔH.

(c) On the axes shown below, sketch the effect of cooling the reaction mixture at time (t_1) on the rates of the forward and backward reactions until the system returns to a new equilibrium at time (t_2).

(3 marks)



endo

endo.

End of part two

PART 3: Extended answer **(80 Marks)**

This part contains **five** questions. You must answer **all** questions. Write your answers in the spaces provided.
Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time for this section is 65 minutes.

Question 1 **(13 marks)**

Chlorine is found in a variety of different acids. Some of these acids are strong acids and some are weak. Chlorine can also exist in different oxidations states. A selection of these acids is shown in the table below.

Name and formula of acid	Strong/Weak
hydrochloric acid $HC\ell$	strong
hypochlorous acid $HOC\ell$	weak
chlorous acid $HC\ell O_2$	weak
chloric acid $HC\ell O_3$	strong
perchloric acid $HC\ell O_4$	strong

(a) What mass of perchloric acid would need to be dissolved in 250 mL of distilled water to produce a solution with a pH of 3.59? (3 marks)

$[H^+] = 10^{-3.59}$

$= 2.57 \times 10^{-4}$

$\therefore [HClO_4] = 2.57 \times 10^{-4}$ mol L^{-1} [1]

$\therefore n(HClO_4) = CV = 2.57 \times 10^{-4} \times 0.250$

$= 6.426 \times 10^{-5}$ mol [1]

$\therefore m(HClO_4) = 6.426 \times 10^{-5} \times 100.5$

$= 6.46 \times 10^{-3}$ g [1]

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1.20 g of solid calcium hydroxide was added to a beaker containing 200 mL of a 0.160 mol L^{-1} aqueous solution of chloric acid, and the solution stirred until the reaction is complete.

(b) Write the balanced ionic equation to show the reaction taking place in the beaker. (2 marks)

$Ca(OH)_{2(s)} + 2H^+_{(aq)} \rightarrow Ca^{2+}_{(aq)} + 2H_2O_{(l)}$

(c) Determine the limiting reagent by calculation. Show your reasoning. (4 marks)

$n(Ca(OH)_2) = \frac{1.20}{74.1}$

$= 0.0162$ mol [1]

$n(HClO_3) = \frac{200 \times 0.160}{1000} = 0.0320$ mol [1]

from eqn 0.0162 mol $Ca(OH)_2$ needs 0.0324 mol $HClO_3$

with 0.0320 mol available [1]

∴ not enough chloric acid – this is the limiting reagent [1]

(d) Calculate the pH of the resulting solution. (4 marks)

from above, 0.0320 mol $HClO_3$ reacts with 0.0160 mole $Ca(OH)_2$

∴ $n(Ca(OH)_2)$ INXS = 0.0002 mol

∴ $n(OH^-)$ = 0.0004 mol [1]

∴ $[OH^-] = \frac{n}{V}$ ← 0.200

$= 0.0020$ mol L^{-1} [1]

∴ $[H^+] = 10^{-14} / 0.002 = 5.0 \times 10^{-12}$ [1]

∴ $pH = -\log [H^+] = 11.3$ [1]

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Question 2 **(17 marks)**

Solutions of iron(II) salts are often used in redox titrations, but can be unreliable as the Fe^{2+} ions can be oxidised by oxygen in the environment, forming various hydrated forms of iron(III) oxide, according to the following equation:

$$Fe^{2+}(aq) + O_2(g) + (2x + 4)\,H_2O(\ell) \rightleftharpoons 2\,Fe_2O_3.xH_2O(s) + 8H^+(aq)$$

Ammonium iron(II) sulfate, or Mohr's salt, is often preferred over iron(II) sulfate for redox titration purposes since the unwanted oxidation of Fe^{2+} is prevented by the ammonium ions present, which reduce the pH of the solution. Mohr's salt is commonly found in hydrated form, as any of a number of salts with the formula $(NH_4)_2Fe(SO_4)_2.\,xH_2O$.

(a) Write an equation to show how the ammonium ions are able to lower the pH of the solution. (2 marks)

$NH_4^+ + H_2O \rightleftharpoons H_3O^+ + NH_3$

(b) Using the initial equation given above explain why the oxidation of Fe^{2+} is prevented in solutions of low pH. (2 marks)

If pH is low then $[H^+]$ is high and a high $[H^+]$ [1] pushes the equilibrium position of the equation to the LHS [1] reducing the unwanted oxidation of Fe^{2+}

10.0 g of hydrated ammonium iron(II) sulfate crystals were dissolved in distilled water and made up to 250 mL in a volumetric flask. 25.0 mL aliquots of this solution were titrated against acidified 0.0240 mol L^{-1} potassium permanganate solution until consistent results were obtained. The table below shows the results of the experiment.

	Rough	1	2	3	4
Final volume (mL)	23.00	21.25	21.25	22.65	23.35
Initial volume (mL)	0.00	0.05	0.00	0.10	2.10
Titre (mL)	23.00	21.20 ✓	21.25 ✓	22.55	21.25 ✓

(c) Complete the table and calculate the average titre volume. (1 mark)

Average titre: $\frac{21.20 + 21.25 + 21.25}{3} = 21.23$ mL

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(d) Write a balanced ionic equation for the reaction taking place between Fe^{2+} and MnO_4^- (2 marks)

$MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$

$5Fe^{2+} \longrightarrow 5Fe^{3+} + 5e^-$

$MnO_4^- + 8H^+ + 5Fe^{2+} \longrightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$.

(e) Calculate the value of x in the formula $(NH_4)_2Fe(SO_4)_2 . xH_2O$. (10 marks)

$n(MnO_4^-) = \frac{21.23 \times 0.0240}{1000}$

$= 5.095 \times 10^{-4}$ mol [1]

$\therefore n(Fe^{2+})$ in 25mL $= 5 \times 5.095 \times 10^{-4}$

$= 2.55 \times 10^{-3}$ mol [1]

$\therefore n(Fe^{2+})$ in 250mL $= 2.55 \times 10^{-2}$ mol [2]

$\therefore n((NH_4)_2Fe(SO_4)_2) = 2.55 \times 10^{-2}$ mol [1]

$\therefore m(\downarrow) = 2.55 \times 10^{-2} \times 284.0$

$= 7.24$ g [2]

$\therefore m(H_2O)$ in compound $= 2.76$ g [1]

	$(NH_4)_2Fe(SO_4)_2$		H_2O
m	7.24		2.76
n	2.55×10^{-2}		0.153
Ratio	1	:	6

$x = 6$. [2]

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Question 3 **(22 marks)**

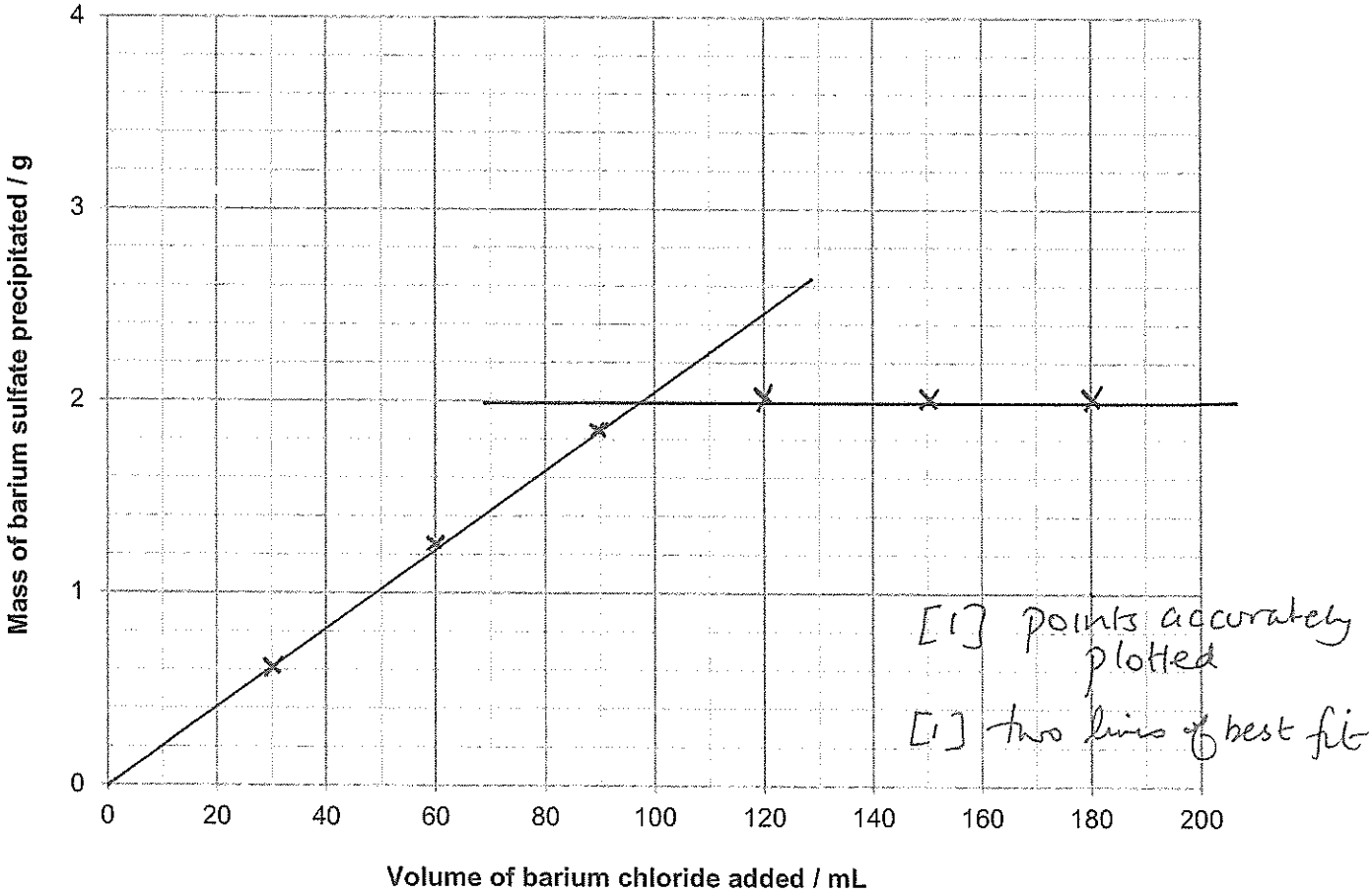
A sample of powdered magnesium sulfate is known to have been contaminated with sodium chloride. The percentage purity of the magnesium sulfate can be determined by the following method:

- 32.50 g of the impure magnesium sulfate is dissolved in water and the solution is made up to 500.0 mL in a volumetric flask.
- Six 20.0 mL aliquots of this solution are placed in separate conical flasks.
- Different volumes of 0.100 mol L^{-1} $BaC\ell_2(aq)$ are added to each flask, causing any sulfate ions present to precipitate out of the solution.
- The precipitate from each sample is filtered, rinsed with distilled water and then dried to constant mass.

The results of this analysis are shown in the table below.

Sample	1	2	3	4	5	6
Volume of $BaC\ell_2(aq)$ added (mL)	30.0	60.0	90.0	120.0	150.0	180.0
Mass of $BaSO_4(s)$ precipitated (g)	0.61	1.23	1.83	2.04	2.04	2.04

(a) Display the results in a suitable format using the axes provided. (2 marks)



(b) Write a balanced ionic equation for the reaction taking place. (1 mark)

$Ba^{2+}_{(aq)} + SO_4^{2-}_{(aq)} \rightarrow BaSO_4(s)$

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(c) Explain why the mass of precipitate remained constant for the last three samples even though more barium chloride was being added. (1 mark)

SO_4^{2-} is the limiting reagent and is all used up.

(d) Use the mass of precipitate to calculate the percentage purity of the magnesium sulfate. (5 marks)

$m(BaSO_4) = 2.04\ g$

$\therefore n(BaSO_4) = \frac{2.04}{233.4}$

$= 8.74 \times 10^{-3}\ mol$ [1]

$\therefore n(MgSO_4) =$ " [1]

$\therefore m(MgSO_4)_{\text{in } 20\,mL} = 1.052\ g$

$\therefore m(MgSO_4)_{\text{in } 500\,mL} = 26.30\ g$ [2]

$\%\ MgSO_4 = \frac{26.30}{32.50} \times 100$

$= 80.9\ \%$ [1]

(e) Use the graph you have drawn in part (a) to estimate the minimum volume of barium chloride needed to precipitate all the sulfate ions from solution. (1 mark)

97 mL accept 95 → 100 [1]

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(f) Calculate the final, total concentration (in mol L^{-1}) of chloride ions in the filtrate collected from **sample four**. You may assume that sodium chloride was the only impurity present in the impure magnesium sulfate. (7 marks)

$n(BaCl_2)$ added $= \frac{120 \times 0.100}{1000}$

$= 0.0120$ mol

$\therefore n(Cl^-)$ added $= 0.0240$ mol [2]

In the 32.50 g sample there is also 6.20 g NaCl

$\therefore n(NaCl)_{\text{in 500mL}} = \frac{6.20}{58.5}$

$= 0.106$ mol

$\therefore n(NaCl)_{\text{in 20mL}} = 4.24 \times 10^{-3}$ mol

$\therefore n(Cl^-) = 0.00424$ mol [2]

total $n(Cl^-) = 0.0240 + 0.0042 = 0.0282$ mol [1]

total volume $= 140$ mL $= 0.140$ L [1]

$\therefore [Cl^-] = \frac{0.0282}{0.140} = 0.201$ mol L^{-1} [1]

(g) Another student carried out a similar analysis, but neglected to rinse the precipitates before drying them. Explain clearly what effect this would have on the student's calculated value of the percentage purity. (3 marks)

↑ mass $BaSO_4$ [1]

$\therefore n(SO_4^{2-})$ ↑

and $n(MgSO_4)$ ↑

$\therefore$ % $MgSO_4$ ↑ [1]

Calculated % of $MgSO_4$ would be too high [1]

The analysis was repeated using six further 20 mL aliquots of the impure magnesium sulfate solution and the same volumes of barium chloride. However, the concentration of the barium chloride solution used was 0.200 mol L^{-1}.

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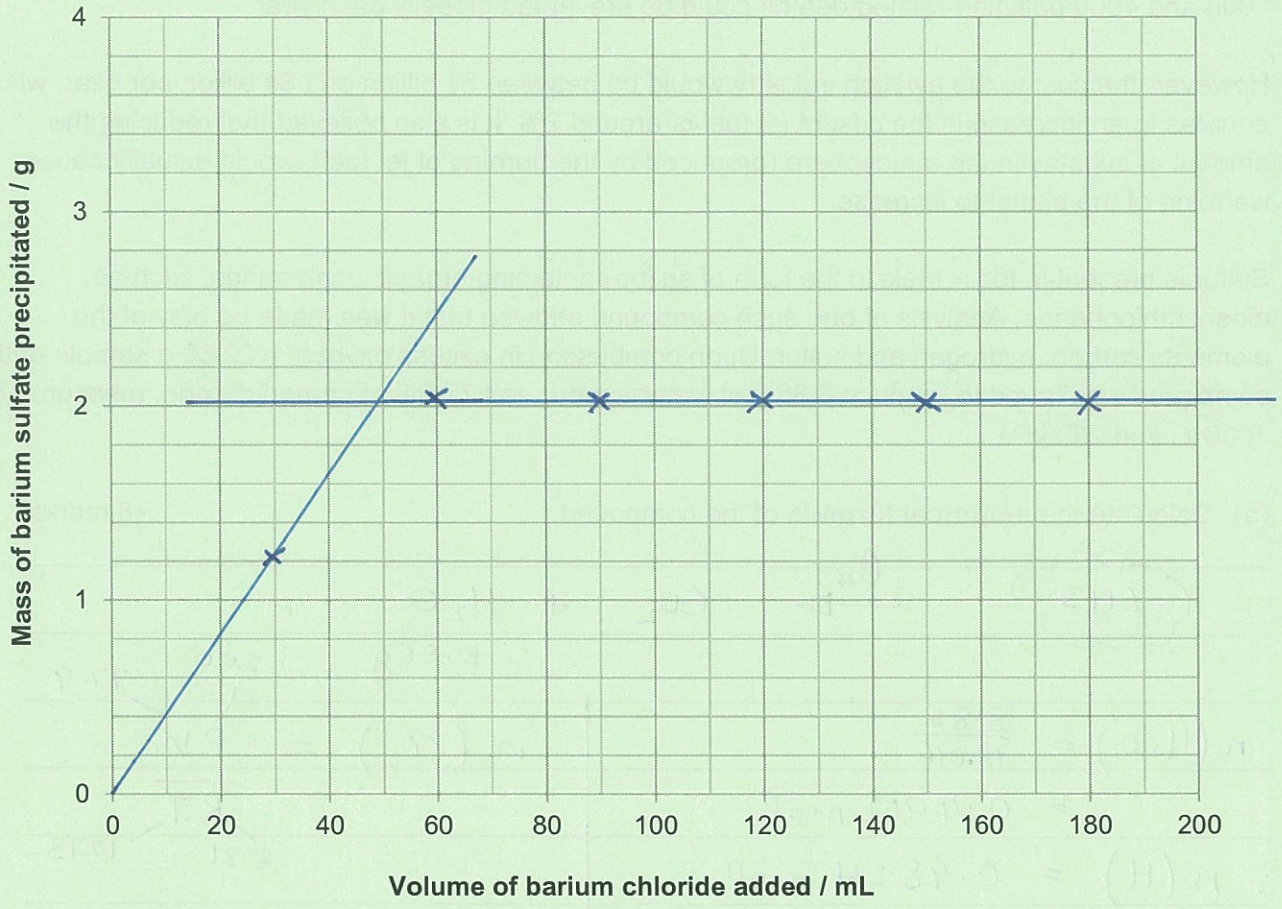
(h) Using the axes below, draw the graph of the expected results when plotting the mass of barium sulfate precipitated against volume of barium chloride added. (2 marks)



[2]

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Question 4 **(17 marks)**

The European Aviation Safety Agency (EASA) have recently sponsored studies into ultra-low sulfur jet (ULSJ) fuel standard. It is estimated that, by reducing the amount of sulfur in jet fuel, between 1000 and 4000 pollution-related deaths could be prevented globally each year.

However, the cost to the aviation industry would be between $1 billion and $4 billion per year, which equates to an increase in the cost of jet fuel of around 2%. It is also believed that reducing the amount of sulfates in the atmosphere (produced by the burning of jet fuel), would actually cause warming of the planet to increase.

Sulfur is present in fossil fuels in the form of sulfur-containing organic compounds, such as dibenzothiophenes. Analysis of one such compound showed that it was made up only of the elements carbon, hydrogen and sulfur. Upon combustion in excess oxygen, a 22.60 g sample of the compound was found to produce 8.85 g of water vapour and 77.9 L of carbon dioxide, measured at 1000°C and 200 kPa.

(a) Calculate the **empirical formula** of the compound. (8 marks)

$CHS \xrightarrow{O_2} CO_2 + H_2O$

$8.85\,g$

$n(H_2O) = \frac{8.85}{18.016}$

$= 0.4912\ mol$

$\therefore n(H) = 0.9824\ mol$

$\therefore m(H) = 0.990\,g$ [2]

$n(CO_2) = \frac{PV}{RT}$ (200, 77.9, 8.31, 1273)

$= 1.473\ mol$

$\therefore m(C) = 17.69\,g$ [2]

$\therefore m(S) = 22.60 - (17.69 + 0.99)$

$= 3.92\,g$

$\therefore n(S) = 0.122\ mol$ [2]

	C	H	S
n	1.473	0.982	0.122
Ratio	12	8	1

[2]

EF $C_{12}H_8S$

Another sample of the compound, weighing 10.71 g, was vapourised in the absence of oxygen. The vapours occupied 1.265 L at 200 kPa and 250°C.

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(b) Use this information and your answer to part (a) to calculate the **molecular formula** of the compound. (3 marks)

10.71 8.31

$M = \frac{mRT}{PV}$ 523

200 1.265

$= 184$ [2]

let M/F = $(C_{12}H_8S)_x$ [1]

$\therefore 184x = 184$ $x = 1$ MF = EF = $C_{12}H_8S$

The ULSJ fuel standard is equivalent to a concentration of sulfur 15 ppm (parts per million).

(c) Calculate the concentration of sulfur in ULSJ fuel in mol L^{-1} if 1L of the fuel weighs 800 g. (~~3~~ 4 marks)

$15\ ppm = \frac{15\ mg\ S}{1\ kg\ fuel}$ [1] *CHANGE TO 4

and 1 kg fuel = $\frac{1000}{800} = 1.25\ L$

$[S] = \frac{n}{V}$ $\frac{15 \times 10^{-3}}{32.1} = 4.67 \times 10^{-4}$ [1]

1.25

$= 3.74 \times 10^{-4}\ mol\ L^{-1}$ [2]

One of the problems associated with the presence of sulfur in fuels is that as rain falls through oxides of sulfur in the atmosphere, they react with the rain. The effect is that the rain becomes acidic.

(d) With the help of equations, explain how these oxides can cause rainwater to become acidic (~~3~~ 2 marks)

need to show production of H_3O^+

*CHANGE to 2

either of the following :

(1) $SO_2 + H_2O \rightarrow H_2SO_3$ [1]

then $H_2SO_3 + H_2O \rightleftarrows H_3O^+ + HSO_3^-$ [1]

or

(2) $SO_3 + H_2O \rightarrow H_2SO_4$ [1]

then $H_2SO_4 + H_2O \rightarrow H_3O^+ + HSO_4^-$ [1]

and $HSO_4^- + H_2O \rightleftarrows H_3O^+ + SO_4^{2-}$

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Question 5 **(11 marks)**

The functional groups present in organic molecules can, by definition, have a strong influence on the chemical properties of those molecules, but they can also play a role in determining the physical properties of substances.

The table below outlines some of the physical properties of four organic substances; pentane, 2,2-dimethylpropane, 2-pentene, and propanoic acid.

	boiling point (°C)	solubility in water	solubility in ethanol
pentane	36.1	low	high
2,2-dimethylpropane	9.5	low	high
pent-2-ene	37.0	low	high
propanoic acid	144.1	high	high

With clear reference to the structure and bonding present, compare and contrast the **chemical and physical properties** of the four substances. You should focus on the physical data provided in the table for the physical properties and use your knowledge of the organic chemistry of the compounds for the chemical properties.

Your answer should include equations where appropriate.

Marks are awarded for clarity of communication. Answers may be written as a series of dot points and diagrams may be used, but care should be taken to ensure that there is a logical sequence of ideas and that any abbreviations or diagrams are explained clearly.

Intermolecular Forces

- **Pentane, 2,2-dimethylpropane and pent-2-ene are all non-polar molecules, so dispersion forces are the only intermolecular force**
- **All the molecules have similar molecular mass, so should be expected to have similar strength dispersion forces**
- **2,2-dimethylpropane has a lower boiling point than pentane and pent-2-ene since its branches prevent molecules from packing as closely together**
- **Propanoic acid is able to form hydrogen bonds**
- **Hydrogen bonds are the strongest intermolecular force, hence highest boiling point for propanoic acid**
- **The dispersion forces that pentane, 2,2-dimethylpropane and pent-2-ene are able to form with water are weak compared to the H-bonds between water molecules, hence they are insoluble in water**
- **However, ethanol can form stronger dispersion forces with pentane, 2,2-dimethylpropane and pent-2-ene than can water, hence all dissolve well in ethanol**
- **Propanoic acid can form strong H-bonds with water and ethanol, making it soluble in both solvents**

Chemical Properties

- **All substances will burn in oxygen to form carbon dioxide and water**
- **e.g.** $C_5H_{12} + 8\ O_2 \rightarrow 5\ CO_2 + 6\ H_2O$
- **Pentane and 2,2-dimethylpropane will react with halogens in the presence of UV light in substitution reactions**
- **e.g.** $C_5H_{12} + Br_2 \rightarrow C_5H_{11}Br + HBr$

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- Pent-2-ene will react with halogens in the dark in addition reactions
- $C_5H_{10} + Br_2 \rightarrow C_5H_{10}Br_2$
- Propanoic acid will react with metals to form a salt and hydrogen (or other typical acid reactions)
- e.g. $2\ CH_3CH_2COOH + Mg \rightarrow 2\ CH_3CH_2COO^- + Mg^{2+} + H_2$
- Propanoic acid will react with alcohols to produce esters
- e.g. $CH_3CH_2COOH + CH_3CH_2OH \rightarrow CH_3CH_2COOCH_2CH_3 + H_2O$
- Pent-2-ene will form addition polymers

Students can score marks for a maximum of 10 points
A mark should be awarded for an answer that is clearly written with points made in a logical order

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